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THE AMERICAN TOAD (BUFO LENTIGINOSUS AMERICANUS, LECONTE)

A STUDY IN DYNAMIC BIOLOGY

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INTRODUCTION

FOR some years it has been my desire to inaugurate a series of university theses aimed distinctively at studying important American species as forces in nature. This kind of work has seemed to me logically the next step in the advance of American natural history. In fact, it is hard to imagine any other line of real advance possible. Species are not discovered, determined, named and classified for the mere sake of making it possible for people to learn their names.

No matter how common the species, when we ask the questions: What does it do in the economy of nature? What position does it occupy in the vital organization of American natural history? What are its relations to human interests? In short, what expression have we of the species as a force in nature? When we ask these questions of the commonest animals, we find ourselves almost as near the verge of human knowledge as with an undiscovered species. No less a man than Darwin himself led off in the field of dynamic biology with his study of "Earthworms and Vegetable Mould." A large number of living forms await study from a similar point of view.

If we determine accurately the work of an individual and multiply this by the number of individuals, we have an expression of the species as a force in nature. Hence it is true, in general, that the commoner or more numerous a species is, the more important its biological work. We accordingly begin this series of dynamic studies with one of the commonest of American animals.

Of the ten species of Bufonidæ now recognized in the United States *B. l. americanus* has the widest range, which includes almost the entire continent of North America east of the Rocky Mountains. It is, therefore, probably the most valuable type of the group.

The insect problem, further, is one of the most important in the entire field of American natural history. It finds partial expression in the annual tax of $795,100,000 which insects impose upon our agricultural resources. This is a rigidly conservative estimate made by the department of agriculture and does not include costs of abating annoyance or losses of household goods or those occasioned by spread of human disease. A large proportion of this loss might be most economically prevented by a reasonable knowledge and utilization of insectivorous animals. With all our books, bulletins and talk about it, we have scarcely made a practical beginning in this direction as a people.

In seeking animal allies to aid in the solution of the insect problem we should choose those which will do the work required most effectively and at the same time present the fewest objectionable features. A good many birds are efficient destroyers of insects, but become injurious if their numbers are unduly increased. Many insects are parasitic and predaceous, but, in general, their breeding or regulation is beyond human control. Clearly an animal to be depended upon to hold insects in check should be one which man can breed in any desired numbers and, on account of the enormous reproductive possibilities of insects, a form which he can increase rapidly. We may do much by way of increase of insectivorous birds, and even bats may prove valuable allies. We may be grateful for the help of predaceous and parastic insects, and good work has been done in importing parasites of foreign insect pests, but clearly we need all the assistance we can find; and all the above agencies are scarcely controllable enough to be depended upon.

For an insectivorous animal which conforms to every requirement of the situation, ease of control and rapid increase, non-injurious, in any numbers, an active feeder in abundance and a patient faster in scarcity, the toad stands probably first on the list among American insectivorous animals. Experiments are now being carried on also with the bob white or American quail with every prospect that this form may prove of equal, if not superior, efficiency, and it will carry added values, in food, sport and weed-seed destruction; but this species is rapidly being exterminated from a large portion of its former range, and it will require a long time for methods of propagation and protection to be worked out and become generally known.

A good deal of unnecessary balancing of accounts has been done of late in attempting to calculate the economic value of species from analysis of the foods. In some cases this has yielded results of some value, but, in general, they have been misleading. Even a small percentage of the gross food of a hawk or shrike, for example, if it consists of a valuable species, might render the predaceous species injurious. In the case of beneficial insects, excepting the honey bee which is under human control, if a species will destroy all the injurious insects, it detracts little or nothing from its efficiency, if it take the beneficial insects as well. This principle applies particularly to the toad, which takes everything in the form of an insect, worm or slug that comes in its way.

Instead of filling its stomach four times in twenty-four hours, as Kirkland estimated, Mr. Miller finds that the toad takes but a single meal a day. This is no discredit to the efficiency of the species. It means, simply, that we should require four times as many to do the work, and, with the number of eggs produced, this offers no difficulty.

Given a pond or even a small pool insured against drying up during the late spring and early summer, and from which natural enemies are eliminated, toads will breed in any desired numbers up to the limits of insect food supply. It would probably, however, be difficult or even impossible to find a single farm in the United States or Canada, although suffering severely from depredations of insects pests—not even the agricultural experiment station farms—which makes any provision whatever for the breeding of toads. In fact, reports so far gathered reveal the fact that farms in the agricultural states of Indiana, Ohio and Illinois are almost entirely destitute of the species. It is probably safe to infer that the toad has been exterminated already from a considerable portion of the cultivated land in the agricultural states. Is this an inevitable result of draining land, and modern methods of tillage? If this be true, can any changes or adjustments be made which will permit the increase of the species? Will the value of the toad's work warrant anything of the kind? Would it pay to establish special breeding places like our present fish hatcheries, or possibly in connection with them?

In order to answer these and many other questions we must have the data of the life and work of the species. To gather these in a manner, if possible, complete enough to serve as a guide and basis for practical action is the purpose of Mr. Miller's work.

The American Toad (*Bufo lentiginosus Americanus* LeConte)

The ancestors of the Bufonidæ first appear as fossils in the Oeningen beds below the Miocene Tertiary strata. The group now has a wide range, being found in all parts of the temperate and torrid world with the exception of Australia and the oceanic islands. The greatest number of species is found in the torrid regions. The

Bufondiæ are represented by nine genera and more than a hundred species. Bufo takes its origin in the Sonoran subregion, *i. e.,* the southwestern part of the United States. It is the only genus found in the United States and is represented by ten species, most of which belong to the southern states. The species *lentiginosus* and its varieties are found throughout the eastern part of the United States and Canada. Two varieties, *americanus* and *fowleri*, share this region (Massachusetts).

Jordan and Cope class the American toad along with Fowler's as a variety of *Bufo lentiginosus.*[1]

My object in this work is to give as completely as possible the entire life and work of one species as normally lived in its own environment. Observations were made continuously throughout the year on the species, *Bufo lentiginosus americanus,* the results of which are given under the heads, Spawning Habits and Seasons; Development, Habits, and Food; Hibernation; and Enemies.

I am indebted to Dr. C. F. Hodge for suggestions while collecting the data for this paper, also for valuable criticisms of the manuscript. He also kindly consented to write the introduction. I wish also to thank Mr. F. E. Chidester for assisting me with the feeding-tests and in obtaining data on the daily life of the toad.

Spawning Habits and Seasons

Observations were made for the springs of 1907 and 1908, but if not otherwise stated the data for this chapter refer to the spring of 1907. Mention is made of 1908 when this season varies from that of 1907.

Toads were first seen in 1907 on the twenty-eighth of March and on the thirteenth of April in 1908. An adult male was found in the water on the night of March 29, 1907, but was so numb that he could not give the usual chirp when picked up. From March 29 to April 21 there was a decided drop in the temperature and toads were not seen again until the night of the twenty-second of April, on which date seven males were found trilling in pond no. 1.[2] Eight days later when the migration to the ponds reached its maximum, mated pairs were abundant on the streets and elsewhere on their way to the water. Trilling began in 1908 on the twenty-third of April and spawning on the twenty-fifth, ending May 13.

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[1] More recently Miss Dickerson has given these toads specific distinction, *i. e., Bufo americanus* and *Bufo fowleri.*

The seven toads mentioned were the first heard trilling this season. They were sluggish and when taken up between the thumb and finger could not chirp, although they made the attempt.

The accompanying curves show the number of toads as well as the number of males and females that were found in pond no. 1 on the night of April 24 and succeeding nights (Fig. 1). Spawn was found here the twenty-sixth. The males were most active on this and the night of the twenty-ninth. On these dates they were trilling vigorously and actively swimming about. If they saw an object moving they swam to it with all possible speed. When it was a male, which was usually the case, he was seized, but loosed as soon as he chirped. They even came

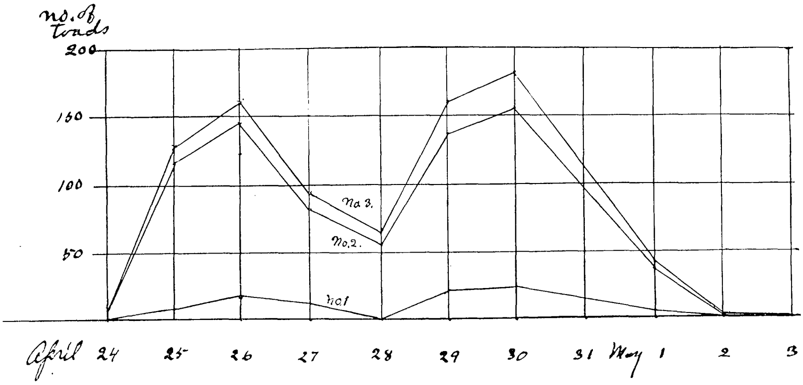

FIG. 1. Curves showing the number of toads in pond, No. 1, during the spawning season. No. 1, Females. No. 2, Males. No. 3, Total.

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[2] This pond is located at the foot of a small steep hill in a pine grove in Park Avenue Place within a hundred yards of a large permanent pond. It is V-shaped, not more than fifteen feet wide by fifty feet long, and during the spawning season was about eighteen inches deep. For the most part it is filled with leaves, some water plants and debris from a near-by dumping ground. Rains are its only source of supply and it goes dry in summer.

to me as I waded out or made a disturbance in the water. All the females on the night of the twenty-seventh and succeeding nights were removed from the pond to the laboratory.

To sum up my observations on this pond we find: first, that the males are the first to reach the water; second, that there were two waves of spawning activity; third, that not less than ninety-two females visited this pond; fourth, that on an average 88.8 per cent. of the toads in the water at any given time during the spawning season were males.

Of eighty-two taken at random from the streets after the breeding season 60.8 per cent. were females. Kellicott gives the proportion of males to females of those collected along Lake Erie, Ohio, as 175:266; King for toads near Bryn Mawr, Pa., 713:823; *i. e.*, 39.7 per cent. 46.5 per cent., respectively, were males.

The females leave the water as soon as they spawn (from six to eighteen hours after reaching the pond). It is probable that the males return to the ponds night after night, which accounts for their apparent excess in numbers during the spawning season.

Observations were made on five ponds, and it was found that the periods of maximum spawning were not simultaneous in all. In no. 1 and no. 2,[3] the spawning period reached its maximum on the nights of April 29 and 30; in no. 3,[4] May 1 and 2; in no. 4,[5] May 14 and 15; in no. 5,[6] May 18 and 19.

[3] Pond no. 2 is at the junction of Park Avenue and Maywood Street. It is a permanent pond of about thirty yards in diameter with a depth of three feet. Around its west, north and east edges is a dense growth of bushes, some growing far out into the water. The south side has its growth of flags and water grasses. To the south and west is an open field, while buildings are near to the east and north.

[4] No. 3 is an overflow of Beaver Brook in an open place just below May Street. This pond is permanent, but the water falls soon after the spring rains to such an extent that most of the spawn is lost.

[5] The pond in University Park is about thirty yards in diameter and has a depth gradually reaching three feet. Its edges are gravelly and the water plants about it are confined to lilies near the west edge. A row of trees is along the north side.

[6] The pond located in Elm Park is a permanent, walled body of water

Why should there be this difference of twenty days between the spawning periods of toads in no. 1 and those in no. 2? It can partially be explained by a cold wave which set in on the fourth of May and stopped laying until the ninth. Even so, the toads in no. 1 had finished spawning before the cold wave came. Neglecting the five days of cold weather, there still remains a difference of fifteen days. These ponds are not more than a mile and a half apart. The elevation is practically the same, also the surroundings. Therefore the environments of the two ponds do not seem sufficiently different to account for so much difference in the spawning periods.

My observations indicate that toads proceed to the ponds immediately after emerging from winter quarters. If this be true, then there is a second laying, or some toads do not come from hibernation until late in June. Observations on one toad in my experiments on hibernation suggest that the latter is true. This female came out for the first time May 28, and if she had gone to the water at once, she would have been thirty-three days later than the first that spawned. I might add that I have seen no large toads among these late layers. All the females are about forty grams or less in size.

The bulk of the spawn for the spring of 1908 was laid in all the ponds between May 2 and 6. A minor period of spawning occurred on the eleventh to thirteenth.

The first few warm days of spring bring out the toads and soon the males are heard in the ponds. In a few more days the females follow and spawning begins at once. I have seen no toad eggs in running water, although there is a small stream within less than two hundred feet of ponds where many toads spawned. However, Dr. Hodge informs me that toads spawn in Rock River, Wis., and Ottawa River, Canada, and Mr. Morse states that toads generally spawn in small streams in Ohio. Toads in this region prefer small ponds in which

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about two hundred yards long by twenty wide. Its depth is probably three feet. Trees surround it and a three-hundred-foot hill rises at its west side. Buildings skirt all sides of the park except the west.

to spawn. Pond no. 1 is within a hundred yards of a large permanent pond, and when there were a hundred or more toads in the former, very few were to be found about the latter.

In natural ponds toads congregate more or less during the spawning season and in a given pond 90 per cent. or more of the eggs are laid within a radius of fifteen feet. In three of the four natural ponds observed the eggs were deposited in an area less than fifteen feet in diameter. Other places similar to those where the spawn was laid existed in these ponds, but were used only by a very few toads if at all. Usually only a portion of the grassy place chosen was used (Fig. 2). The artificial pond in University Park gives almost the same results. Here the edges are kept clean and the toads had to deposit their spawn on the bottom. Nevertheless, all the eggs laid here before May 4 were deposited in an eight by ten foot strip of the north shore. Later, May 9–15, eggs were laid all along the north and northeast sides, with a few scattered spawn along the south. The two or three

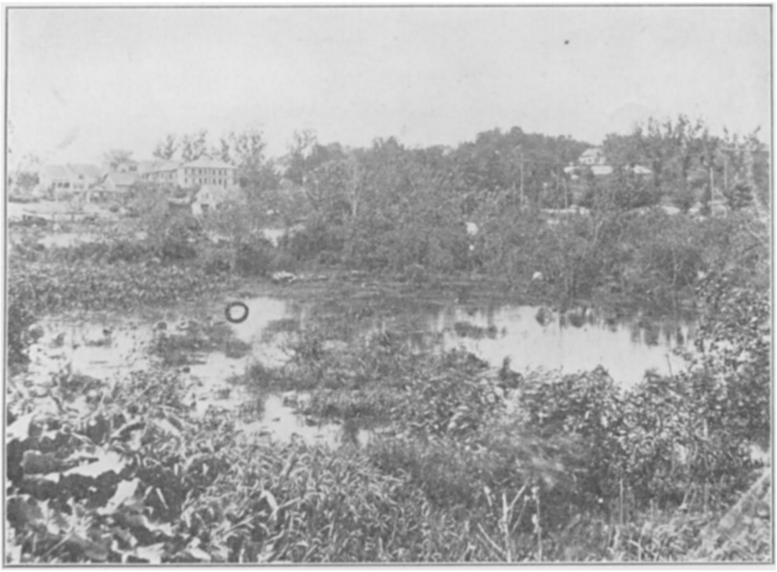

FIG. 2. Pond No. 1. Circle shows the spawning place.

pairs that may occasionally be found in ponds during the latter part of May and June may deposit their eggs any place about the ponds. I found a little colony of some twenty pairs June 4–8 laying in a space not more than six feet in diameter in an overflow of Beaver Brook. My observations for the spring of 1908 on the same ponds confirm the above statements. The spawn in the various ponds was deposited in almost exactly the same places as the previous year.

Since in general only limited areas are used for spawning it would indicate that there is some choice among toads for spawning grounds. This is done by the males, but without the purpose of having the spawn deposited in such and such a place. They reach the water two or three days before the females and begin their trilling. They seek out each other and repeatedly attempt copulation with one another. In this way all the males in the pond are soon brought together. Even a day or two before the females arrive they are assembled, usually, on some grassy spot out in deep water, to which they return after a fruitless attempt to mate with other males. The females, following the trill of the males, come at last to this circle where they mate and lay. Thus these resting places of the males eventually become the spawning grounds. The observations of Mr. Courtis, later repeated by myself, support the view that the females come to the males.

The spawning place is usually a grassy plot well out in the pond where the dead grass or weeds come to within two or three inches of the surface. In artificial ponds where such places do not exist a shallow place along the edge is used. In the former case the female, as a rule, does not go down to lay, while in the latter practically all spawning is done under water.

Should it turn cold while the toads are spawning they leave the water until the temperature again rises. Meanwhile, they may be found concealed in the grass or leaves, or sunning themselves at the edge of the pond, often the male still clinging to the female with which he had mated before leaving the water.

As with all amphibians the eggs are fertilized outside of the body. In mating the male clasps the female just back of her fore legs and then places his hind feet upon her thighs. This is the position maintained throughout except at intervals during oviposition. The intervals are about fifteen minutes apart. At such times the female straightens her body, raises her head, and stretches her hind legs backwards. The male hooks his feet between the female's hind legs, thus forming a basket between the feet and legs of the male and the legs and body of the female. (Fig. 3.) In this basket are now deposited probably two or three hundred eggs, while simultaneously the male ejects his sperm. Boulenger is no doubt mistaken in the purpose of this process when he writes that the male (*B. vulgaris*) aids the female in

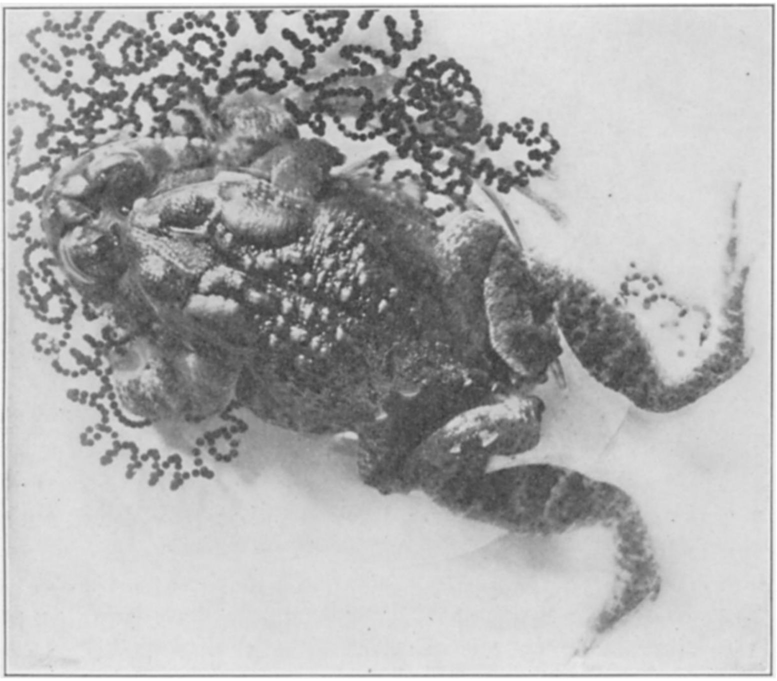

FIG. 3. Shows the formation of the basket in which the eggs are fertilized.

oviposition by pulling the eggs strings with his toes. That the male ejects his sperm at this time was demonstrated by microscopical examination of a slide applied to the anus of the male just before and during oviposition. In the former case, very few if any spermatozoa were found, while, in the latter, they were found in abundance.

As soon as the eggs and sperm are ejected the toads remain quiet, holding the mass in the improvised basket perfectly quiet from one to three minutes. This is ample time for the spermatozoa to get well attached to the eggs, since fertilization takes place within four minutes from the time the eggs leave the oviduct. The female now moves along, stretching out the strings of eggs just laid.

Most of the eggs are deposited in water not more than ten inches deep. Those found in weedy and grassy places are, usually, not over four inches under water. In University and Elm Park ponds where the toads were much disturbed, a large number of eggs was deposited some distance from the edge at a depth of eighteen inches or more. This deep laying seemed of no particular disadvantage, since a toad can remain underwater as long as fifteen minutes, which is ample time to fertilize the eggs and stretch out the egg strand.

The eggs are encased in a continuous, cylindrical, gelatinous strand of three to four millimeters in diameter. The gelatinous coat is added in the oviduct, and as soon as ejected absorbs water and swells. In this way there is a mass of .0225 gram of jelly-like substance about each egg, which serves as a means of protection. Eggs removed from the ovary weigh on an average .0024 gram and measure 1.1 to 1.2 mm. in diameter. When laid they are variously spaced in the strands even of the same spawn (Fig. 4). Sometimes they are crowded together so that as many as three may be in the same cross-section, or again regularly spaced at intervals of about 1 mm. The strings may be laid by either twos or fours. I have not observed in smaller toads (under 7 cm.) more than two strands being deposited at the same time, but in the larger females four are not uncommon. The time required for oviposition varies between six and eighteen hours.

The number of eggs in spawns may be said to vary with the sizes of the toads. Thus females 6 cm. long lay about 4,000 eggs while a toad 9 cm. long may lay 15,000. The smallest spawn observed consisted of 3,929 eggs and the largest 15,835. These were laid in the laboratory.

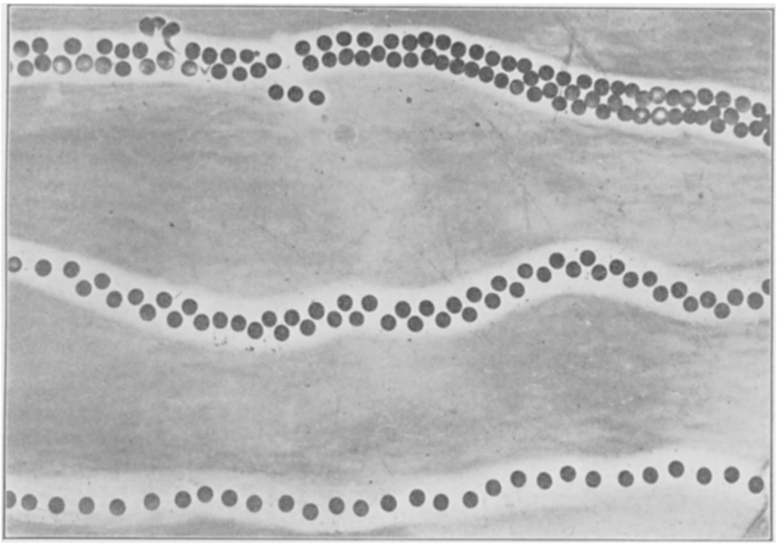

FIG. 4. Spacing of the eggs as seen in a single spawn.

On making some computations on the largest spawn, we find that the eggs weigh 38 grams and with the gelatinous covering, 394 grams. This latter weight is about five times the weight of the toad. Again, allowing a space of 1.5 mm. for each egg, we get 41 meters, or 134 feet as the length of the strings.

Only the males trill or make any sounds. While trilling the mouth and nostrils are closed and a pouch under the throat is inflated. Trilling in the full strong note was observed only in connection with mating. Miss Dickinson describes the call as follows:

> The sustained note is not only high pitched and tremulous, it seems to have a dual character as though a low note was droned at the same

> time that the high one is whistled. Imitate the call by whistling the upper and at the same time humming the lower of the following notes:

Concerning the call of the toad after the breading season she writes:

> I have heard this feeble note of the toad in August only some half dozen times (the toads were under observation in "moss garden" in the house).

One of the toads in experiment no. II. gave this call April 5, 6 and 22. I heard at least ten toads giving this feeble note on the afternoon of the twenty-first of September, 1907, and at night of the same date just before a thunder storm. In 1908 this trill was heard as late as September 26. This note is not at all similar to that of the breeding season. It is about the same pitch but much weaker, more guttural, and not so long. The trill is not so distinct as in the spring call.

It has already been stated that on an average 88.8 per cent. of all the toads in a pond at any given time are males. Thus, for every female there are seven males. Often a male clasps a female before she reaches the water and she must carry him to the pond. At the pond a lively scene follows until the female with her mate reaches the spawning place. I have often observed two or three males clasping the same female and a few instances of four. In such cases the female is helpless and is usually held underwater. Darwin states on the authority of Dr. Günther that a female is sometimes drowned during the struggle among the males. In these contests the male always gets hold of the female, for he will not hold another male.

The one that first clasps the female in the mating position can not be dislodged, no matter how much stronger his rivals may be. The female, if she is in the water, helps her partner evade the other males by diving or sinking. This she does repeatedly and to good advantage during oviposition.

Males can not distinguish at sight males from females. For this reason they are continually clasping one another. They have a call of three or four notes which they utter in rapid succession when taken up between the finger and thumb, or clasped by another male. This seems to be a warning signal, for a male will release another as soon as he chirps. In ponds males fight over a dead male as though it were a female. They will clasp anything moving or which touches their breast that they can hold.

It was mentioned above that spawn was deposited at a depth of eighteen inches or more in certain ponds. This depth appeared to be unusual, still the eggs developed normally. The following experiment was made with 500 eggs to test the effect of depth on hatching. One hundred eggs were placed in each of five tumblers over the tops of which were stretched pieces of cheese cloth. These tumblers were then attached six inches apart to a stick which was fastened upright in pond no. 2.

The experiment was started the twenty-first of May. The eggs in the lowest vessel developed much faster than those in the top, apparently as much as a day ahead. This can probably be explained by the fact that a cold wave came the day the experiment was started and continued for four or five days. Thus the surface was cooled more than the deeper water, but the final result of the hatching of the eggs at different depths was the same. A similar experiment made in pond no. 4 gave uniform development for eggs at depths between six and twenty-four inches. From these data it is seen that depth to as much as twenty-four inches does not affect materially the hatching of the eggs.

Counts made on eggs in various places show that 68 per cent. to 90 per cent. are fertile. On an average, development begins in 85 per cent. of the eggs.

DEVELOPMENT, HABITS AND FOOD

The toads leave the water as soon as they spawn. Development proceeds rapidly in the eggs from which tadpoles emerge within two to six days, depending upon the temperature. At this time the larva is about 3 mm. long without mouth or appendages. On the under side of its head behind the buccal area are two small crescent-like depressions known as "sucking disks." These are glands, however, and it is by their sticky secretion and not by suction that the tadpole attaches itself to objects.

For a day or two after hatching the tadpoles cling most of the time to the gelatinous strings or near-by plants. The tail is noticeably compressed on the second day and the larva makes excursions from time to time, eventually reaching the shallow water. The mouth is formed in three to seven days, and the larvæ begin feeding. Henceforth the tadpole is a voracious feeder, living largely upon the slime at the bottom of the pond and that collected upon sticks and plants. Meats, fresh or putrid, are eagerly devoured and vegetable matter is also eaten. In this way the tadpoles play the part of scavengers (Fig. 5).

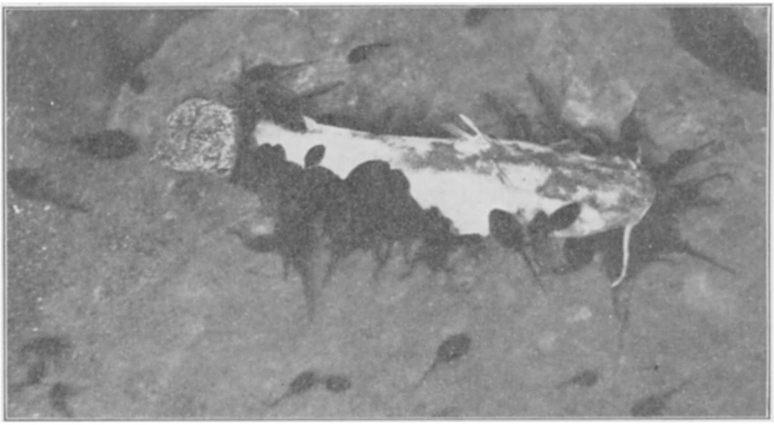

FIG. 5. Toad tadpoles feeding on a pout in a natural pond.

The first gills are external and are soon replaced by internal ones.

The first indication of transformation is the growth of the legs. They appear as small knobs or buds about the twentieth day of the tadpole's life. Both pairs grow rapidly and within ten days may be fully formed. The front legs, concealed in the gill chamber, appear suddenly a short time before the tadpole leaves the water. One is thrust out at the breathing pore and the other breaks directly through the operculum. The tadpole is now almost ready to abandon its aquatic life and within a day it may do so. A few days previous to this time, the tail has begun to shrink and by the second day out of the water may be completely absorbed. Meanwhile great changes take place in the region of the head. The eyes become enlarged and elevated; the larval beak or jaws are lost; the mouth broadens and a tongue forms; the gill slits close and the lungs mature. The long coiled alimentary canal shortens and differentiates into stomach and intestine. The color changes from a jet black to a brownish tinge with faint spots. The skin is yet perfectly smooth. All of this growth, development and metamorphosis from the egg to the completion of the toad may take place in thirty-two days, or two hundred, as in the case of some kept in the laboratory in a poorly fed condition.

The following table is given to show the rate of growth and development.

TABLE I

	Total Length, mm.	Body Length, mm.	Hind Leg, mm.	Weight, Grams.
April 29, eggs laid.				.0024
May 4 larvæ still in the gelatin.	3.5			
“ 5 “ “ “ “ “	4.2			
“ 7 “ “ “ “ “	6.0			
“ 9 “ out of the gelatin	7.0			
“ 11 “ “ “ “ “	8.0			
“ 13 “ “ “ “ “	9.2			.0157
“ 15 “ “ “ “ “	10.5			.0132
“ 19 “ “ “ “ “	11.0			.0199
“ 21 “ “ “ “ “	12.0			.0295
“ 23 “ “ “ “ “	15.0			.0385
“ 25 “ “ “ “ “	17.0			.0566
“ 27 “ “ “ “ “	19.5		1.0	.0901
“ 29 “ “ “ “ “	22.0		2.0	.1310
“ 31 “ “ “ “ “	23.0		2.5	.1561
June 2 “ “ “ “ “	22.4		2.5	.1560
“ 4 “ “ “ “ “	23.8	9.5	3.0	.1460
“ 6 “ “ “ “ “	23.4	10.0	3.5	.1570
“ 8 “ “ “ “ “	24.4	10.0	4.0	.1680
“ 10 “ “ “ “ “	25.8	10.0	5.7	.1700
“ 10 largest specimen.	28.0	10.5	7.0	.2200
“ 12 one transformed.	25.2	10.0	8.7	.1520
“ 14 “ “	10–25.0	10.0	11.0	.1020
“ 18 all metamorphosed.	10.0	10.0	11.5	.0796

The weight given for the eggs is that previously determined for those removed from the ovary. To weigh the tadpoles, they were placed upon a glass slide covered with filter paper which was moistened sufficiently to keep the tadpoles alive. The larvæ, slide, etc., were weighed, and then, removing the tadpoles by means of a dissecting needle, the slide, etc., were again quickly weighed. This method gave me the weight desired without killing the tadpoles. There was of course some evaporation and loss of water in removing the larvæ. But, since it was aproximately the same for each weight, the data are not affected to any great extent.

This table is the average weight and measurements of eighteen tadpoles which were kept in a vessel by themselves with water plants. Their food was mostly dog-biscuit with a little meat.

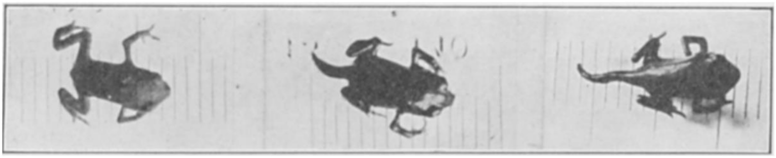

FIG. 6. Transformation. *a*, day before leaving the water; *b*, just leaving the water; *c*, day after leaving the water.

Toads just metamorphosed were seen for the first time on the morning of the twenty-third of June. During the next ten days most of the toads of the early spawn abandoned the ponds. The number leaving the water at this time is probably 90 per cent. of all that emerge during the summer. At this time eggs and tadpoles in all stages and toads just metamorphosed could be found in the same pond. Tadpoles were in the ponds as late as August 15. Larvæ from eggs laid April 29th were kept in the laboratory until October 20.

Newly emerged toads are so susceptible to transpiration that they must remain in damp places for a few days. Many remain near the ponds in the grass, under stones, etc., during the day, thereby escaping the fate of those wandering away too soon. At nights or on cloudy days during the time that tadpoles are transforming, the vicinity of ponds may be alive with young toads migrating from the water.

The great numbers that leave the water or places of hiding during a rain, have led to the belief that toads are rained down.

After abandoning their aquatic life, these little toads simply eat, grow and endeavor to escape their enemies. By the first of October, their weight at the time of metamorphosis has been increased more than sixty times. In other words, they double in weight almost every sixteen days.

Reports indicate that toads are very unequally distributed both as to the country in general and to local areas. Killicut found them abundant along Lake Erie in Ohio. Here in Massachusetts they are very numerous. Through the northern half of Indiana toads can almost be said to be scarce, while in the southern half they are found in considerable numbers. Few were observed in the vicinity of Waterloo, Iowa. Reports from Wisconsin and Minnesota indicate that this species is well represented in these states, while in Maine and Ohio they are said to be abundant.

Toads are more numerous in and about towns than elsewhere. Very rarely is a toad seen in a large field which is under cultivation. Only fifty toads were seen during a whole season on one thousand acres of farming land in central Indiana. This scarcity may be accounted for by two factors, *i. e.,* first, that pasturing and tillage kill the toads or, second, that the extensive drainage has exterminated the toad by depriving it of breeding places. Sufficient data are not at hand, as yet, upon these two points of general and local distribution to draw conclusions.

During the summer the toad leads a solitary life and no more utters the ringing trill of the breeding season. On very rare occasions, which may be as late as September 21, he may strike up a weak, shorter and more guttural note, which is much inferior to the vigor and fullness of the mating call. This note is so rare that the toad may be considered silent throughout the summer.

Rarely, except at night or on cloudy days, is the toad seen hopping about. Late in the fall, however, he may be found sunning himself in the grass. At this time he is sluggish and apparently only waiting for cold weather to put him to sleep. Toads come out of their hidings on rainy days, and, especially, on nights following rainy days. I counted fifty-two toads in a vacant lot between 7:00–8:00 P.M., July 22, after a hard rain in the afternoon. Counts repeated here for the next nine days at the same time in the evening varied between 0 and 16, and most of the times there were less than six toads to be seen. On the twenty-second many of this year's toads were seen, but on the following nine days, scarcely one could be found. In general, throughout the summer the toad passes the day in concealment in damp sheltered places, while the night, the toad's day, is spent in foraging.

Some of the toads in the above observation of July 22 were shedding their skins, and many appeared to have just done so. This process is frequent and often takes place immediately after the toad comes from its place of concealment.

The one in experiment IV shed her skin every seventh to eleventh day, or on an average once every 8.2 days from October 23 to April 8. Those in Experiment III did not shed so often nor as regularly; some going as long as four weeks without shedding, unless they did so in their burrows. I have seen some indications that shedding is done while the toad remains buried, and the process may be frequent and regular although the toad remains concealed.

The process is accomplished by pushing the skin forward to the neck by the hind feet and then pulling it off over the head by the fore feet. That on the hind legs and feet is rubbed off against the sides of the body, while that on the fore legs and feet is pulled off by the jaws. The skin is removed from the feet and legs in a manner very similar to that of seizing a glove by the top and turning it wrong side out as it is pulled off. As the skin is raked over the head it is seized by the jaws and swallowed. Previous to the removal of the skin, the new skin secretes a viscid substance that loosens the old from the new and leaves the body moist for a short time after the old skin has been shed. The whole process is accomplished in about two minutes.

The following is a record of the work done by an adult male (weighing 36 g.) in twenty-seven hours. The distance traveled in this time was 85 feet, and the number of insects taken, 23. Twenty hours and five minutes were spent in burrows and, for the rest of the time, the toad was active only one hour and forty-seven minutes. It is probable that the period of activity from 7:20–8:40 A.M. would have been lessened had not another toad entered the burrow of the one under observation and forced him out. More than half of the total distance traveled in the twenty-seven hours was covered in quest of a second burrow. The following is the time spent in the burrows.

July 25, 1:50 P.M.–7:55 P.M.
July 25, 11:50 P.M.–2:30 A.M.
July 26, 4:05 A.M.–7:20 A.M.
July 26, 8:40 A.M.–4:00 P.M.

The food taken consists entirely of animal matter. Mineral or vegetable material is often found in the toad's stomach, but it is there by accident. I have found as much as 0.07 gram of coal and sand in the stomach of a 5.5-gram toad; it had just swallowed its skin and along with it the coal and sand which stuck to it. I have also seen pieces of grass, winged seeds and other bits of plants snapped up and swallowed with insects.

The amount a toad will eat in twenty-four hours seems somewhat astonishing if we were to judge from various reports. Miss Ellen M. Foskett records one feeding of a large toad as ninety to one hundred rose beetles. She also adds that "the toad showed no signs of wishing to conclude his meal." Kirkland found "the remains of seventy-seven myriapods in a single stomach, fifty-five army worms in another, sixty-five gypsy moth caterpillars in a fourth. In these cases, however, but one kind of food was present and the toads were above the usual size." He states further, on the authority of Mr. J. E.

Wilcox, that a toad ate twenty-four fourth moult gypsy moth larvæ in ten minutes; again, on authority of F. H. Mosher, that a toad ate thirty to thirty-five full-grown celery worms in three hours at intervals of about twenty minutes. Eighty-six house flies are recorded by Dr. C. F. Hodge as being snapped up in less than ten minutes. Dr. J. R. Slonaker fed an eighty-gram toad all the beefsteak and flies it would eat for two days. On the first day, December 7, it ate 2.8 grams of beefsteak and three flies; on the second, 3 grams of beefsteak and twelve flies. From further feeding he concluded that his toad would eat on an average forty flies per day.

A. H. Kirkland, H. Garman and F. A. Hartman have given us much valuable information on the food of the toad from careful analyses of stomach contents. Kirkland examined one hundred and forty-nine stomachs collected from April to September, of which he gives the folling as a fair specimen. The toad was killed at 9:00 P.M. May 11, 1896, and found to contain: "9 ants (*C. Pennsylvanicus*), 6 cutworms, 5 myriapods (Julius sp.), 6 sowbugs (Parcello sp.?), 1 weevel (*Hylobius pales*) and 1 carabid beetle (Pterastichus sp.?)"; total 28. Kirkland's report shows that 84 per cent. of the toad's food consists of 28 per cent. lepidopterous insects and their larvæ, 27 per cent. beetles, 19 per cent. ants, 10 per cent. myriapods. The insects alone were represented by eighty species.

The five records which follow are those of Garman.

No. 20, a toad 1⅛ inch long, obtained on the Experiment Farm, August, 1896. 2 *Drasterius elegans,* 1 *Diabrotica 12-punctata,* 1 *Sytena tæmata,* 1 millipede (Polydesmus), 1 bug, fragments of ants, 6 chinch bugs and fragments of others.

No. 1, a toad of medium size, captured beneath an electric burner, Lexington, Ky., Oct. 1, 1894, had eaten 27 ants, 19 sowbugs, 3 spiders, 1 caterpillar, and 10 plant-lice; total 60.

No. 2, a toad 1 inch long, captured in a celery patch, Lexington, Ky., Sept. 2, 1891, had eaten 14 ants and 1 caterpillar; total 15.

No. 3, captured in a strawberry patch, Lexington, Aug. 5, 1890, had eaten 2 large ground beetles, 1 tiger beetle, 1 corn root-worm beetle, 1 lady beetle, 8 small ground beetles and 9 ants; total 22.

No. 4, taken Lexington, July 26, 1890, had eaten 2 Colorado potato beetles, 1 click beetle, 4 bugs (Cydnidæ), 1 tiger beetle, 1 moth, 7 ground beetles, 6 ants, 1 millipede and 1 sowbug; total 24.

The above data on six stomachs are given in order to show what a toad feeds upon while in its natural habitat. So far as known a toad will eat any arthropod, mollusc or worm that it can easily swallow, without regard to spines, stings, noxious odor or taste. The question then is, in determining the economic importance of the toad's feeding habits, not to know how much it can or will eat, but to know, *how much it actually does eat.* Owing to the slow digestive rate of the toad, stomach examinations give us a close approximation to the desired information.

It is stated by Kirkland that a toad will fill its stomach four times per day. This seemed to me to necessitate rather rapid digestion for a cold-blooded animal, and I made the following experiment to test it.

August 8, a female weighing 35 grams was killed thirteen hours after having fed on three Colorado potato beetles and two grasshoppers. Examination of the stomach showed the beetles still entire. The grasshoppers had disintegrated, but none of the food had passed from the stomach.

August 26, 2:00 P.M., two toads, nos. 1 and 2, weighing seven and twenty-five grams, respectively, were fed chiefly on grasshoppers. Eighteen hours later, no. 1 was killed and at the end of twenty-two hours, no. 2. All of the food was still in the stomach of no. 1 but well digested. Stomach no. 2 contained a portion of the food, but most had passed into the intestine.

August 30, 11:30 P.M., a toad weighing twenty grams was fed on two beetles, two grasshoppers and one fly. When examined eight hours later the stomach showed: the grasshoppers well digested, but not disintegrated and the fly and both beetles still entire.

These tests demonstrate that a toad can not fill its stomach more than once in twenty-four hours. A toad will eat at intervals when its stomach is only partially filled, but to completely fill it four times a day is out of the question.

Test No. I

Date. 1907.	Toad No. 1. Weight 58.		Toad No. 2. Weight 56.		Toad No. 3. Weight 24.		Toad No. 4. Weight 16.		Toad No. 5. Weight 6.4.		Toad No. 6. Weight 15.		Toad No. 7. Weight 25.		Toad No. 8. Weight 30.		Toad No. 9. Weight 35.		Toad No. 10. Weight 34.	
	No. of insects.	No. of grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.
Aug. 3	40	3.5	37	3.8	60	2.8	15	1.2	29	3.0	42	3.9	30	3.0	28	3.0	27	3.2	40	3.8
" 4	60	3.7	37	3.8	2	1.2	0	0.0	0	0.0	0	.0	15	1.4	40	2.5	0	0.0	0	0.0
" 5	0	0	15	4.1	13	2.5	0	0.0	2	.11	14	1.6	18	1.3	0	.0	0	0.0	0	0.0
" 6	25	2.1	22	2.5	37	3.1	0	0.0	0	0.0	0	0.0	69	1.6	19	13	0	0.0	17	.67
" 7	30	3.0	42	3.5	27	1.4	0	0.0	11	.22	0	0.0	37	2.4	0	.0	0	0.0	0	0.0
" 8	6	1.9	36	2.6	45	3.8	0	0.0	0	0.0	0	0.0	14	1.4	0	.0	0	0.0	63	0.7
Totals.	161	14.1	189	16.0	184	14.0	15	1.2	42	3.0	56	3.7	183	10.7	113	9.1	27	3.2	130	5.1

Test No. II

Date. 1908	Toad No. 1. Weight 71.		Toad No. 2. Weight 64.		Toad No. 3. Weight 49.		Toad No. 4. Weight 46.		Toad No. 5. Weight 50.		Toad No. 6. Weight 37.		Toad No. 7. Weight 33.		Toad No. 8. Weight 35.		Toad No. 9. Weight 26.		Toad No. 10. Weight 16.	
	No. of insects.	No. of grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams
June 19	30	1.5	45	2.0	36	1.5	15	0.5	39	0.6	165	3.8	42	1.7	0.0	0.0	40	1.6	17	0.7
" 20	25	1.7	152	5.1	28	1.8	38	2.8	35	1.4	80	3.2	39	1.3	0.0	0.0	21	0.6	38 S	1.7
" 21	34	1.3	23	1.5	33 S	2.3	50 S	2.0	60 S	5.1	40 S	2.5	21 S	0.7	3.5	3.0	13	0.6	49	2.7
" 22	S	1.8	3	1.1	43	3.2		2.7	25	4.1		0.5	23	1.8	2.6	1.7		1.1	35	1.7
" 23		5.7		2.5		4.0		3.0		3.6		0.5	S	1.4		1.5		2.6		1.7
June 24							Insects could not be obtained on account of rain.													
	×	×	×	×	× S	×	×	×	×	×	× S	×	×	×	×	×	×	×	×	×
" 25		0.3		0.5		0.0		0.8		0.5		0.0		0.0		0.3		0.6		0.2
" 26		0.2		2.0		0.0		0.2		0.0		0.0		0.5		0.1		0.0		1.0
" 27	S	0.0	S	0.3		0.0		1.2		0.0		0.1		0.0		0.2		0.0		0.5
Totals.		12.5		15.0		12.8		12.2		16.3		10.6		7.4		6.8		7.1		10.2

Test No. III

Date. 1908.	Toad No. 1. Weight 49.		Toad No. 2. Weight 50.		Toad No. 3. Weight 45.		Toad No. 4. Weight 40.		Toad No. 5. Weight 33.		Toad No. 6. Weight 34.		Toad No. 7. Weight 28.		Toad No. 8. Weight 24.		Toad No. 9. Weight 27.		Toad No. 10. Weight 42.	
	No. of insects.	No. of grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.	insects.	grams.
July 23		3.0		3.5		0.5		0.3		1.3		1.5		2.0		2.5		1.6		2.1
" 24		2.0		2.7		0.2		0.6		1.1		1.5	S	1.6		D		D		0.0
" 25		D		D		0.5		0.9		D		0.0		2.4		D		D		D
" 26		0.0		D	S	0.0	S	2.5	S	0.0		2.4		4.5		3.1		D		D
" 27	S	0.2		3.6		D		2.0		2.1	S	1.2	S	3.7		2.5		2.5		2.7
" 28		0.8		D		D		1.8		D		0.0		D		D		1.9		2.0
" 29		D		4.6		D		2.0		1.6		1.7	S	2.4		D		D		1.6
" 30		0.6		D		D		D	S	1.0		0.4		D		1.2		1.5		1.5
" 31		D	S	2.0		D		0.2		0.5		0.0		1.8		D		D		2.0
Aug. 1		D		D		D		0.8		D		1.6		D		0.5		D		D
" 2		D		D		D		D		D		D		1.0		D		D		D
" 3		0.8		D		D		D	S	D	S	1.8		0.4		D		D		D
" 4						D														
" 5						D														
Totals.		7.4		16.4		1.2		11.2		7.6		12.1		19.8		9.8		7.5		11.9

Average amount eaten per day, 11.2 grams.
Average weight of the toads, 36.6 grams.
Average amount eaten per day per toad, 1.12 grams.

S = times toads were observed shedding their skins.
D = days toads remained buried.
0.0 = days toads refused to eat when not buried.

The results given in the following table are of feeding tests made in order to see how much and how often a toad will eat. The tests were made with sweepings and, as grasshoppers formed the greater part, the experiment was carried on largely with them. This, I think, does not affect the experiment to any great extent, since toads show very little preference, if any, for certain species of insects. If toads are placed in cages with sweepings, various species are taken at random, provided only that they be moving and of a size easily swallowed.

Ten toads, half males and half females, were chosen for each test. Each toad was confined separately in a glass cage (4 × 5 × 7 inches) in which was about two inches of moist earth. Throughout test no. I, insects were kept constantly before the toads. The insects were weighed and counted, then put into the cages with the toads. In test no. II the toads were allowed to feed, one at a time, in a wire cage containing insects. The cage with the insects was weighed before the toad was put in and then weighed again after the toad was removed. Allowance had to be made for loss by evaporation in determining the amount eaten. A more satisfactory cage was constructed entirely of glass for test no. III. It measured 8 × 10 × 10 inches and had on its bottom a half inch of dry sand for the absorption of moisture. Evaporation from this cage was less than a gram in ten hours. Insects were placed in it and the process of weighing followed as in test no. II.

In nos. I and III the toads were not disturbed unless they were out of the earth. But in no. II they were dug up every day, if necessary, in order that they be offered food at least once.

The following are the results of the three feeding tests.

The data show that for test no. II the toads feed oftener than in the other two experiments, but that the amount eaten, in proportion to the weight of the toads, is 3 and 2 per cent. less than in tests nos. I and III, respectively.

The time represented in these experiments is equal to that of one toad for 260 days, 96 of which were passed without feeding. In other words, a toad refuses food on 36.9 per cent. of the days. Therefore instead of a toad filling its stomach four times in twenty-four hours, according to Kirkland, it may eat (probably fill its stomach) once in a day and a half. The average amount eaten per toad per day in these 260 days is 1.12 g. The average weight of the toads is 36.6 grams, which is about the weight of the largest males or of a medium-sized female.

These feeding tests show that the amount eaten at one feeding compares very closely with the stomach contents as recorded by Garmann, Hartman, and Kirkland. Furthermore they demonstrate: (1) That the stomach of a toad is not a rubber bag with an unlimited capacity as commonly supposed; (2) that the toad when feeding, if food is abundant, soon fills its stomach; (3) that toads do not feed every day. This was suspected, since toads are seen in greater numbers on rainy nights.

Usually as soon as the toads fed they buried themselves and remained so from one to ten days. Sometimes their eyes and nostrils were left exposed. Even so, insects placed in their cages usually failed to tempt them to leave their burrows.

If we take the mean, 36.6 grams, as an average sized toad, we find that it eats on an average, 26 insects or 1.12 grams per day. Counting May, June, July and August as a toad's feeding months, it will eat in this time some 3,200 insects, or 134.4 grams.

To estimate the value of a toad's work in dollars and cents is rather difficult, since the toad eats beneficial as well as harmful insects. Garman from his data does not hesitate to class the toad with useful animals, yet he would not have us overlook the number of beneficial insects eaten. According to Kirkland eleven per cent. of its food consists of insects directly or indirectly valuable to man and eighty per cent. is either directly injurious or obnoxious. He computes on the data previously given of a stomach content that a toad is worth $19.88 per year for the cutworms alone which it destroys. He assumes that a toad fills its stomach four times a day with 6 cutworms and other insects for three months and that the cutworms do damage to the amount of one cent each. Granting that cutworms are injurious to the amount of one cent each and that they work four months instead of three, still Kirkland's estimate is about four times too large, for a toad can not fill its stomach more than once in twenty-four hours. Furthermore, my experiments show that it eats, on an average, only once in one and a half days. These factors give the toad a value of about $5 per year on the basis of Kirkland's estimate. Such figures may be approximately correct for greenhouses, gardens or truck farms, but on the whole I am inclined to think they are too large for farming districts.

(*To be concluded*)